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OPINION PAPER

A comment on "Changing estuaries, changing views"

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Abstract The provision of flood safety is of paramount importance in densely populated deltaic regions. The Dutch rely on flood defences to protect their lives and livelihoods from large-scale floods. The paper "Changing estuaries, changing views" (Smits et al., Hydrobiologica 565:339–355, 2006) criticizes this strategy and presents an alternative that could be summarized as a proposal to leave deltas untouched and to rely on natural sedimentation to reduce the impact of floods. It seems questionable, however, whether such a strategy will often be compatible with population pressures and efforts to stimulate economic growth. Moreover, it presupposes morphological conditions that seem highly unrealistic, not just in the Netherlands but also in many other sediment-starved coastal systems. Other than recommending countries not to implement the Dutch flood protection strategy and to leave deltas untouched, it should be recommended that solutions be tailored to local circumstances. The choice of a flood protection strategy should be based on a balanced evaluation of alternatives, including a realistic assessment of physical conditions.

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Ever since the first water boards were established in the 13th century, the Dutch have relied upon dykes to protect themselves from floods. The article "Changing estuaries, changing views" (Smits et al., 2006, vol. 565: 339–355) presents an alternative that could be summarized as a proposal to leave deltas untouched and adapt socio-economic activity to the natural system. This could be a viable flood protection strategy in exceptional cases such as the Yellow River Delta, a relatively untouched prograding deltaic system. However, the realities of coastal morphology and economic life will often necessitate a compromise between a vibrant, untouched deltaic region and a safe and prosperous society. The choice between these two extremes should, at a minimum, be based on a realistic assessment of socio-economic and environmental impacts, as well as physical (here: morphological) conditions. Several recommendations by the authors of "Changing estuaries, changing views" however fail that test. The criticisms of the Dutch present-day flood defense strategy, as well as the suggested solution to leave deltas untouched, rest on assumptions that are highly disputable.

The authors of "Changing estuaries, changing views" note that "From a socio-economic point of view, the impression of safety bestowed by the massive dykes, invited people to invest money behind them" (Smits et al., 2006: 343). They therefore recommend not to construct dykes (Smits et al., 2006: 353). Investments in low-lying regions indeed increase potential damage, but should investments in delta regions also be interpreted as an unintended and detrimental side-effect of dyke strengthening? Stimulating or safeguarding socio-economic progress has been and still is a centerpiece of government policy. Such a policy is a major drive for human intervention in delta regions. The lower the probability that individuals lose their lives and livelihoods in floods, the more attractive a delta becomes (ceteris paribus). The fact that the Netherlands has become a prosperous nation despite being located in the once swampy flood-prone delta of the Rhine and Meuse rivers points to the success of the Dutch flood risk management strategy. We do acknowledge though that environmental health may require a different protection strategy than a strategy based on socio-economic progress alone.

When governments are supposed to act upon the preferences of their individual citizens, flood protection and subsequent socio-economic development should be encouraged rather than remedied. A flood defense is the archetypal example of a public good: it is characterized by non-rivalry and non-excludability. No matter how many people are protected, a flood defense system protects everyone just the same, although damages may differ, e.g., due to topographical effects. The marginal costs of extending flood protection to an additional individual are zero. A flood defense system therefore becomes increasingly attractive when the population within its confines grows larger. While potential damages increase when people invest in areas protected by dyke rings, subsequent investments in flood protection result in a *per capita* decrease in flood risks and costs of flood protection.

Although the authors of "Changing estuaries, changing views" rightly note that "tens of millions are spent each year to keep the civil-engineering constructions in good condition" (p. 345), it should be noted that these amounts are fairly modest considering the sizable population and valuable assets that the Dutch flood defenses protect. Although 60% of the Netherlands lies below sea level, annual spending on flood protection in the Netherlands is only 0.15% of GDP, hardly a worrying figure (RIVM-MNP, 2004). This figure shows that the Dutch flood protection strategy is highly cost effective, contrary to suggestions by Smits et al. (2006). The suggested alternative to flood defense, i.e., leaving deltas untouched and adjusting socio-economic processes to the natural system, would certainly compromise economic growth. Secondly, it would by no means be without investment or maintenance cost as infrastructures and houses that can cope with regular floods are more expensive than infrastructures and houses in an environment in which flooding is the exception rather than the rule.

Despite the low annual expenditures to maintain and upgrade the Dutch flood defenses, the level of flood safety provided is exceptional. The major revision of the Dutch flood safety policy that followed the last major flood in 1953 led to organizational changes and more stringent design standards, codified by the Flood Defense Act. While no flood risk management strategy could guarantee perfect safety, another 1953 storm surge could easily be withstood by the present Dutch primary flood defenses.

But what about the future? The sea level rises and the land subsides. Indeed, "the combination of the rising sea level and subsidence of the reclaimed land (particularly the peat areas) dramatically changed the difference between sea and land. Most polderland now lies far below the level of the sea" (Smits et al., 2006: 343). The first suggested solution would be to construct no dykes, opt for open estuaries, and avoid drainage of dry land (Smits et al., 2006: 352). The second suggested solution would be to embank islands, opt for open estuaries, and avoid overstrained drainage of dry land (Smits et al., 2006: 352). Both solutions rest on the premise that incidental flooding would allow the land to rise with the sea, but would the land indeed rise with the sea? Could the speculative conclusion be supported that "a delta without dykes is safer than a delta with dykes, because natural processes will weaken the effects of extreme storm floods" (Smits et al., 2006: 352)? Would natural sedimentation processes indeed "provide a durable alternative to the unreliable dykes" (Smits et al., 2006: 352)?

Unfortunately, for the Dutch estuaries as well as for many other sediment-starved coastal systems, the answer is no. A geological reconstruction of the Dutch delta including its estuaries (the Waddensea and the Zeeland estuaries) teaches us that, although sedimentation has occurred in the central Almere lagoon between 6000 and 4000 years BP primarily through marine sediment feeding under high sea-level rise rates (Beets et al., 1992), it has not been strong enough to elevate the land above mean sea level. An illustration of this is the recent discovery of an ancient agricultural field at Swifterbant on the eastside of the lagoon by archaeologists. The discovery was made 2 m below Flevopolder land level, 6 m below mean sea level. The Almere lagoon transformed into the Zuiderzee several hundred years ago, when the Waddensea lagoon evolved and connected to the Almere lagoon after transgression in the North by slow but continuing sea-level rise (Beets et al., 1992). Another illustrative example concerns the Biesbosch, a freshwater tidal natural reserve that was created in 1421 by the St. Elizabeth flood. Despite its open connection to the sea from 1421 to 1850, it still lies only 0.5 m above mean sea level, offering little protection against extreme floods. Although estuaries provide sediment accommodation space under sea-level rise (Cowell et al., 2003), it is expected that increasing rates of sea-level rise will result in the drowning of estuaries, rather than an equilibration of the subaqueous morphology (Van Goor et al., 2003).

And even if land would rise with the sea, low-probability extreme storm surges could still have devastating consequences without flood defenses. A storm surge with an exceedance frequency of 1/10,000 per annum (which is the design standard for the flood defenses that protect Central Holland) would raise the sea level by several meters. While such a surge might hit the Dutch only after thousands of years, it could also hit next year. Relying on natural sedimentation to protect lives and properties against such low-probability, extreme events would hardly be effective. A delta with dykes is never perfectly safe, but a Dutch delta without dykes would certainly be less safe. The statement that “dykes can never guarantee full safety” (Smits et al., 2006: 353) is correct, but it deserves a closer look. No flood risk management strategy can guarantee perfect safety: there will always be a probability, however remote, that things will go horribly wrong. A dyke that is, say, 1 km wide and 50 meters high would be extremely reliable. But it would also be extremely costly. The key question, as with any flood protection strategy, is how much we are willing to invest in exchange for risk reduction. The probability of dyke failure is therefore the result of democratic decision-making.

Investments should in our view be based on the costs of flood protection (including the present value of maintenance cost and environmental impacts) and its gains (including economic growth). The flexibility of alternative strategies should also be taken into account when choosing between flood risk management strategies, as correctly noted by Smits et al. (2006: 354). Arrow and Fisher (1974) have proven that a bias towards reversible decisions becomes rational under uncertainty and a prospect for learning: flexible solutions present us the (quasi-)option to change course. Conrad (1980) has shown that the value of this (quasi-)option is equivalent to the expected value of information. To illustrate the origins of (quasi-)option value, consider a rational decision maker who is asked to appraise the construction of a polder that would produce certain agricultural profits worth b relative to, e.g., aquaculture in the unspoiled state. Impoldering might however cause an irreversible loss q. A priori, the decision maker subjectively estimates this probability to be p. Denote the decision maker’s utility function by U and initial wealth by w. The rational decision maker will undertake the activity when $(1-p)U(w+b)+pU(w+b-q)>0$. Now let us consider the case in which the decision maker could also postpone the activity and wait for the results of a study that would show with certainty (for reasons of simplicity) whether the impoldering would be harmful or not. By postponing the impoldering, the decision maker would have effectively bought an option not to polder. The option only expires worthless when the impoldering turns out to be safe. But when it turns out to be harmful, the decision maker will exercise his or her option and refrain from impoldering. The option thus has a non-negative value. However, the option comes at a cost, as returns are depressed during the waiting period. The decision maker will only postpone the impoldering when the option’s value exceeds the gains forsaken.

This simple model illuminates an important point: flexibility is valuable, but it is only part of the bigger picture. Flexibility comes in a variety of forms. Dykes are, for instance, less costly to adapt to rising sea levels than properties and infrastructures built on artificial hills. Given the opportunity cost of capital, postponing investments until they are needed is preferable over having to overinvest considerably to avoid possible regret. The authors of "Changing Estuaries, Changing Views" however refer to another type of flexibility: the option not to have to (possibly) face and mitigate environmental degradation. A decision maker would be well advised to leave a delta untouched if the value of this (quasi-)option were to exceed the gains that would be forsaken. But when the prospect for learning is dim, or when the (potential) exercise date of the option lies far into the future, the option's present value will be low. And even when the option is valuable (or harm certain), the present value of gains forsaken could be greater.

In densely populated areas, where socio-economic pressures are considerable and growth rates are in the order of 2% per annum, it seems unlikely that it would make economic sense to adjust modern socio-economic life to the slow pace of natural processes rather than the other way round. In sparsely populated areas however, the view of "a society in balance with nature" (Smits et al., 2006: 351) might be more appropriate. But again, much depends on technological possibilities, the realities of socio-economic life, physical conditions, and social preferences. In a complex world, there are no simple, generic answers.

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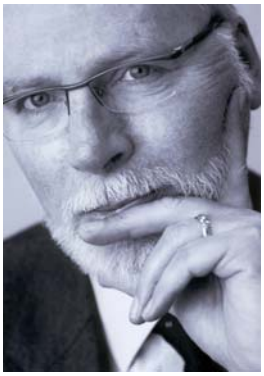
Author Biographies

R. B. Jongejan received a master's degree in Civil Engineering at Delft University of Technology in 2004, and a master's degree in Political Science at Leiden University in 2007. In September 2004, he started as a PhD student at the faculty of Civil Engineering of Delft University. His main research interests are risk regulation and reliability engineering, with a particular focus on industrial and flood risks. Besides his studies at Delft University, he serves on two committees of the Netherlands Hazardous Substances Council, and works as a consultant in the field of risk management.

J. K. Vrijling received a master's degree in Civil Engineering in 1977 at Delft University of Technology. In 1980 he received a master's degree in Economics at the Erasmus University Rotterdam. After a short period at the engineering office of the Adriaan Volker Group he was seconded to the Easternscheldt storm surge barrier project. In this project, Mr. Vrijling developed the probabilistic approach to the design of the barrier. After the completion of the barrier in 1986 he became deputy head of the hydraulic engineering branch of the Civil Engineering Division of Rijkswaterstaat. In 1989 he was responsible for the research and computer activities of the Civil Engineering Division. In 1989 he became professor in Hydraulic Engineering in Delft University of Technology. Since 1995 he has been full professor in Delft, and adviser to the Civil Engineering Division of Rijkswaterstaat.



M. J. F. Stive received an MSc degree in Civil Engineering in 1977 and a PhD degree in Civil Engineering in 1988, both at Delft University of Technology. He has 30 years experience in research and projects in the fields of hydraulic engineering, coastal morphodynamics, coastal bio-geomorphology and coastal and estuarine management, as team member, as team leader, and as adviser. His record involves coasts, estuaries, harbors, and offshore projects in Europe, Asia, Africa and the Americas, using fieldwork and experimental physical and mathematical physical models. He spent two years as visiting professor at the Universitat Polytecnica de Catalunya, and was part-time professor of Coastal Morphodynamics at Delft University of Technology from 1994 to 2000. In 2001 he accepted the full-time chair of Coastal Engineering at Delft University of Technology. Since 2003 he has been scientific Director of the Water Research Centre of Delft University, and since 2006 has been course director of the EU Erasmus Mundus MSc course on coastal and marine engineering and management. He is a member of the Coastal Engineering Research Council of the American Society of Engineers. He has written many publications on a variety of topics, ranging from geology to hydraulic engineering and coastal zone management.

S. N. Jonkman received a master's degree in Civil Engineering at Delft University in 2001. Between 2001 and 2007 he worked for the Ministry of Transport, Public Works, and Water Management in the Netherlands. During this period, he was actively involved as an adviser in the changes that took place in the Dutch flood risk management policies. From 2002 to September 2007, he also conducted PhD research at Delft University. His dissertation was titled 'Loss of life estimation in flood risk assessment—theory and applications'. In this dissertation, new methods were proposed for the quantification of loss of life and risks of (amongst other) flooding. After the flooding of New Orleans in 2005, he assisted the reconstruction effort in an advisory role, and conducted research in the affected area. In September 2007 he became consultant at Royal Haskoning's Coast and Rivers division. He is also a part-time lecturer at the Faculty of Civil Engineering and Geosciences of Delft University of Technology.